

WHAT IS CLAIMED IS:

1 1. A gas concentration detecting apparatus for use in a limit-current type gas
2 concentration sensor comprising a sensor element including a solid electrolyte and
3 a pair of electrodes placed on said solid electrolyte so that an element current
4 flows in corresponding relation to a specific component concentration whenever a
5 voltage is applied to said sensor element, with the applied voltage being
6 controlled on the basis of an applied voltage characteristic defined linearly and
7 said specific component concentration in a gas to be detected being detected in a
8 wide range on the basis of an output of said element current, said applied voltage
9 characteristic being set on the basis of a width of a limiting current region on each
10 concentration level in a gas concentration detection range.

1 2. A gas concentration detecting apparatus for use in a limit-current type gas
2 concentration sensor having a sensor element including a solid electrolyte and a
3 pair of electrodes placed on said solid electrolyte so that an element current flows
4 in corresponding relation to a specific component concentration whenever a
5 voltage is applied to said sensor element, said apparatus comprising:
6 an applied voltage control unit connected to said electrodes of said sensor
7 element for controlling the applied voltage on the basis of an applied voltage
8 characteristic defined linearly; and
9 an element current detecting unit connected to said electrodes of said
10 sensor element for detecting an element current output corresponding to a specific
11 component concentration in a gas to be detected in a gas concentration detection
12 range set widely,
13 said applied voltage characteristic being set on the basis of a width of a
14 limiting current region on each concentration level in said gas concentration
15 detection range.

1 3. The apparatus according to claim 1, wherein an upper limit or one point on
2 said limiting current region in the vicinity of said upper limit in said gas
3 concentration detection range is specified and a lower limit or one point on said
4 limiting current region in the vicinity of said lower limit in said gas concentration
5 detection range is specified, with an applied voltage line being set as said applied
6 voltage characteristic to pass through said points specified.

1 4. The apparatus according to claim 2, wherein an upper limit or one point on
2 said limiting current region in the vicinity of said upper limit in said gas
3 concentration detection range is specified and a lower limit or one point on said
4 limiting current region in the vicinity of said lower limit in said gas concentration
5 detection range is specified, with an applied voltage line being set as said applied
6 voltage characteristic to pass through said points specified.

1 5. The apparatus according to claim 1, wherein said gas concentration
2 detection range is divided into a plurality of portions, and an upper limit or one
3 point on said limiting current region in the vicinity of the upper limit in each
4 detection range portion is specified and a lower limit or one point on said limiting
5 current region in the vicinity of the lower limit in each detection range portion is
6 specified, with an applied voltage line serving as said applied voltage
7 characteristic being set to pass through said points specified.

1 6. The apparatus according to claim 2, wherein said gas concentration
2 detection range is divided into a plurality of portions, and an upper limit or one
3 point on said limiting current region in the vicinity of the upper limit in each
4 detection range portion is specified and a lower limit or one point on said limiting
5 current region in the vicinity of the lower limit in each detection range portion is
6 specified, with an applied voltage line serving as said applied voltage
7 characteristic being set to pass through said points specified.

1 7. The apparatus according to claim 1, wherein said limiting current region is
2 determined on the condition that a variation of said element current is below a
3 predetermined quantity, and said applied voltage characteristic is set to pass
4 through an intermediate point of said limiting current region.

1 8. The apparatus according to claim 2, wherein said limiting current region is
2 determined on the condition that a variation of said element current is below a
3 predetermined quantity, and said applied voltage characteristic is set to pass
4 through an intermediate point of said limiting current region.

1 9. The apparatus according to claim 1, wherein, when said applied voltage to
2 said sensor element is increased, said limiting current region is set between a first
3 voltage point at which an output of an electromotive force coming into a balance
4 with said applied voltage starts and a second voltage point at which a
5 decomposition of water contained in said gas to be detected starts.

1 10. The apparatus according to claim 2, wherein, when said applied voltage to
2 said sensor element is increased, said limiting current region is set between a first
3 voltage point at which an output of an electromotive force coming into a balance
4 with said applied voltage starts and a second voltage point at which a
5 decomposition of water contained in said gas to be detected starts.

1 11. The apparatus according to claim 1, wherein said apparatus is made to
2 detect a specific component concentration in an exhaust gas emitted from a
3 combustion engine, and said limiting current region is set between a first voltage
4 point at which, when said applied voltage to said sensor element is increased, an
5 output of an electromotive force coming into balance with said applied voltage
6 starts and a second voltage point at which said element current increases due to

7 the residue of a reaction-hard component of unburned components contained in
8 said gas to be detected.

1 12. The apparatus according to claim 2, wherein said apparatus is made to
2 detect a specific component concentration in an exhaust gas emitted from a
3 combustion engine, and said limiting current region is set between a first voltage
4 point at which, when said applied voltage to said sensor element is increased, an
5 output of an electromotive force coming into balance with said applied voltage
6 starts and a second voltage point at which said element current increases due to
7 the residue of a reaction-hard component of unburned components contained in
8 said gas to be detected.

1 13. The apparatus according to claim 11, wherein an intermediate point
2 between said first and second voltage points is specified to set an applied voltage
3 line as said applied voltage characteristic.

1 14. The apparatus according to claim 12, wherein an intermediate point
2 between said first and second voltage points is specified to set an applied voltage
3 line as said applied voltage characteristic.

1 15. The apparatus according to claim 1, wherein, in a voltage range in which
2 said element current becomes approximately constant with respect to said applied
3 voltage in a sensor output characteristic, a voltage range except a voltage range in
4 which water contained in said gas to be detected is decomposed is set as said
5 limiting current region.

1 16. The apparatus according to claim 2, wherein, in a voltage range in which
2 said element current becomes approximately constant with respect to said applied
3 voltage in a sensor output characteristic, a voltage range except a voltage range in

4 which water contained in said gas to be detected is decomposed is set as said
5 limiting current region.

1 17. The apparatus according to claim 1, wherein, on voltage-current (V-I)
2 coordinates representing the relationship between said applied voltage and said
3 element current therein, an inclination (I/V) of an applied voltage line serving as
4 said applied voltage characteristic is made smaller than an inclination (I/V) of a
5 resistance governing region determined in accordance with a direct-current
6 internal resistance of said sensor element.

1 18. The apparatus according to claim 2, wherein, on voltage-current (V-I)
2 coordinates representing the relationship between said applied voltage and said
3 element current therein, an inclination (I/V) of an applied voltage line serving as
4 said applied voltage characteristic is made smaller than an inclination (I/V) of a
5 resistance governing region determined in accordance with a direct-current
6 internal resistance of said sensor element.

1 19. The apparatus according to claim 1, wherein different applied voltage
2 characteristics are set in a gas concentration detection range in which widths of
3 limiting current regions are approximately equal to each other and in a gas
4 concentration detection range in which widths of limiting current regions are
5 different from each other.

1 20. The apparatus according to claim 1, wherein different applied voltage
2 characteristics are set in a gas concentration detection range in which widths of
3 limiting current regions are approximately equal to each other and in a gas
4 concentration detection range in which widths of limiting current regions are
5 different from each other.

1 21. The apparatus according to claim 1, wherein, in a plurality of sensor
2 output characteristics whose temperature conditions of the sensor element differ
3 from each other, an applied voltage line is set to pass through a region in which
4 limiting current regions overlap.

1 22. The apparatus according to claim 2, wherein, in a plurality of sensor
2 output characteristics whose temperature conditions of the sensor element differ
3 from each other, an applied voltage line is set to pass through a region in which
4 limiting current regions overlap.

1 23. The apparatus according to claim 21, wherein an output characteristic at a
2 minimum temperature in a temperature range actually attainable in a using
3 environment of said sensor element and an output characteristic at a maximum
4 temperature therein are employed so that said applied voltage line is set to pass
5 through a region in which limiting currents of said output characteristics overlap.

1 24. The apparatus according to claim 22, wherein an output characteristic at a
2 minimum temperature in a temperature range actually attainable in a using
3 environment of said sensor element and an output characteristic at a maximum
4 temperature therein are employed so that said applied voltage line is set to pass
5 through a region in which limiting currents of said output characteristics overlap.

1 25. The apparatus according to claim 1, wherein an initial output characteristic
2 of said sensor element and an estimated output characteristic thereof after
3 variation with time are used so that an applied voltage line is set to pass through a
4 region in which limiting current regions of said output characteristics overlap.

1 26. The apparatus according to claim 2, wherein an initial output characteristic
2 of said sensor element and an estimated output characteristic thereof after

3 variation with time are used so that an applied voltage line is set to pass through a
4 region in which limiting current regions of said output characteristics overlap.

1 27. The apparatus according to claim 25, wherein said estimated output
2 characteristic after the variation with time is an estimated output characteristic at a
3 deterioration tolerance limit permitting the use of an output of said element
4 current.

1 28. The apparatus according to claim 26, wherein said estimated output
2 characteristic after the variation with time is an estimated output characteristic at a
3 deterioration tolerance limit permitting the use of an output of said element
4 current.

1 29. The apparatus according to claim 1, wherein a sensor characteristic line
2 and an applied voltage line are set so as not to intersect with each other in a region
3 outside a gas concentration detection range defined in advance.

1 30. The apparatus according to claim 2, wherein a sensor characteristic line
2 and an applied voltage line are set so as not to intersect with each other in a region
3 outside a gas concentration detection range defined in advance.

1 31. The apparatus according to claim 1, wherein excess current detecting
2 means is provided to detect that said element current is outside a range defined in
3 advance, and said applied voltage characteristic is changed when said excess
4 current detecting means detects said element current in the exterior of the defined
5 range.

1 32. The apparatus according to claim 2, further comprising excess current
2 detecting means for detecting that said element current is outside a range defined

3 in advance so that said applied voltage characteristic is changed when said excess
4 current detecting means detects said element current in the exterior of the defined
5 range.

1 33. The apparatus according to claim 31, wherein, when said excess current
2 detecting means detects that said element current is outside the defined range, said
3 applied voltage characteristic is made to be changed to a voltage limiting applied
4 voltage characteristic for suppressing excess voltage application to said sensor
5 element, while a timing of the change of said applied voltage characteristic is
6 delayed at the detection of said element current outside the defined range.

1 34. The apparatus according to claim 32, wherein, when said excess current
2 detecting means detects that said element current is outside the defined range, said
3 applied voltage characteristic is made to be changed to a voltage limiting applied
4 voltage characteristic for suppressing excess voltage application to said sensor
5 element, while a timing of the change of said applied voltage characteristic is
6 delayed at the detection of said element current outside the defined range.

1 35. The apparatus according to claim 1, wherein an applied voltage control
2 circuit made to feedback-control the applied voltage on the basis of said element
3 current controls the applied voltage on the basis of the set applied voltage
4 characteristic.

1 36. The apparatus according to claim 2, further comprising an applied voltage
2 control circuit made to feedback-control the applied voltage on the basis of said
3 element current, said applied voltage control circuit controlling the applied
4 voltage on the basis of the set applied voltage characteristic.

1 37. The apparatus according to claim 35, wherein said applied voltage control
2 circuit includes voltage change regulating means for regulating a change of the
3 applied voltage.

1 38. The apparatus according to claim 36, wherein said applied voltage control
2 circuit includes voltage change regulating means for regulating a change of the
3 applied voltage.

1 39. A gas concentration detecting apparatus for use in a limit-current type gas
2 concentration sensor comprising a sensor element including a solid electrolyte and
3 a pair of electrodes placed on said solid electrolyte so that an element current
4 flows in corresponding relation to a specific component concentration whenever a
5 voltage is applied to said sensor element, with the applied voltage being
6 controlled on the basis of an applied voltage characteristic defined linearly and
7 said specific component concentration in a gas to be detected being detected in a
8 wide range on the basis of an output of said element current, and in a
9 predetermined concentration range, a low-voltage side characteristic defined by
10 connecting low-voltage side end points of limiting current regions on
11 concentration levels and a high-voltage side characteristic defined by connecting
12 high-voltage side end points of the same limiting current regions thereon are
13 defined so that said applied voltage characteristic is set on the basis of an
14 intermediate inclination between the inclinations of said low-voltage and
15 high-voltage side characteristics.

1 40. A gas concentration detecting apparatus for use in a limit-current type gas
2 concentration sensor having a sensor element including a solid electrolyte and a
3 pair of electrodes placed on said solid electrolyte so that an element current flows
4 in corresponding relation to a specific component concentration whenever a
5 voltage is applied to said sensor element, said apparatus comprising:

6 an applied voltage control unit connected to said electrodes of said sensor
7 element for controlling the applied voltage on the basis of an applied voltage
8 characteristic defined linearly; and

9 an element current detecting unit connected to said electrodes of said
10 sensor element for detecting an element current output corresponding to a specific
11 component concentration in a gas to be detected in a gas concentration detection
12 range set widely,

13 in said applied voltage control unit, a low-voltage side characteristic
14 defined by connecting low-voltage side end points of limiting current regions on
15 concentration levels and a high-voltage side characteristic defined by connecting
16 high-voltage side end points of the same limiting current regions thereon are
17 defined in a predetermined concentration range so that said applied voltage
18 characteristic is set on the basis of an intermediate inclination between the
19 inclinations of said low-voltage and high-voltage side characteristics.

1 41. The apparatus according to claim 39, wherein said low-voltage side
2 characteristic is defined by a voltage point at which, when the applied voltage to
3 said sensor element is increased, an output of an electromotive force coming into
4 balance with respect to the applied voltage starts, while said high-voltage side
5 characteristic is defined by a voltage point at which decomposition of water
6 contained in said gas to be detected starts.

1 42. The apparatus according to claim 40, wherein said low-voltage side
2 characteristic is defined by a voltage point at which, when the applied voltage to
3 said sensor element is increased, an output of an electromotive force coming into
4 balance with respect to the applied voltage starts, while said high-voltage side
5 characteristic is defined by a voltage point at which decomposition of water
6 contained in said gas to be detected starts.

1 43. The apparatus according to claim 39, wherein the apparatus is a gas
2 concentration detecting apparatus which is made to detect a specific component
3 concentration of an exhaust gas emitted from a combustion engine, and said
4 low-voltage side characteristic is defined by a voltage point at which, when the
5 applied voltage to said sensor element is increased, an output of an electromotive
6 force coming into balance with respect to the applied voltage starts, while said
7 high-voltage side characteristic is defined by a voltage point at which said element
8 current increases due to the residue of a reaction-hard component of unburned
9 components contained in said gas to be detected.

1 44. The apparatus according to claim 40, wherein the apparatus is a gas
2 concentration detecting apparatus which is made to detect a specific component
3 concentration of an exhaust gas emitted from a combustion engine, and said
4 low-voltage side characteristic is defined by a voltage point at which, when the
5 applied voltage to said sensor element is increased, an output of an electromotive
6 force coming into balance with respect to the applied voltage starts, while said
7 high-voltage side characteristic is defined by a voltage point at which said element
8 current increases due to the residue of a reaction-hard component of unburned
9 components contained in said gas to be detected.

1 45. A gas concentration detecting apparatus for use in a limit-current type gas
2 concentration sensor comprising a sensor element including a solid electrolyte and
3 a pair of electrodes placed on said solid electrolyte so that an element current
4 flows in corresponding relation to a specific component concentration whenever a
5 voltage is applied to said sensor element, with the applied voltage being
6 controlled on the basis of an applied voltage characteristic defined in advance and
7 said specific component concentration in a gas to be detected being detected in a
8 wide range on the basis of an output of said element current,

9 the applied voltage to said sensor element is controlled between a voltage
10 point at which, when the applied voltage to said sensor element is increased, an
11 output of an electromotive force coming into balance with respect to the applied
12 voltage starts and a voltage point at which decomposition of water contained in a
13 gas to be detected starts.

1 46. A gas concentration detecting apparatus for use in a limit-current type gas
2 concentration sensor comprising a sensor element including a solid electrolyte and
3 a pair of electrodes placed on said solid electrolyte so that an element current
4 flows in corresponding relation to a specific component concentration whenever a
5 voltage is applied to said sensor element, with the applied voltage being
6 controlled on the basis of an applied voltage characteristic defined in advance and
7 said specific component concentration in a gas to be detected being detected in a
8 wide range on the basis of an output of said element current,
9 of a voltage range in which said element current becomes approximately
10 constant with respect to the applied voltage in a sensor output characteristic, a
11 voltage range excluding a voltage range in which water contained in a gas to be
12 detected is decomposed is set as a limiting current region, and the applied voltage
13 is controlled in said limiting current region.

1 47. A gas concentration detecting apparatus for use in a limit-current type gas
2 concentration sensor comprising a sensor element including a solid electrolyte and
3 a pair of electrodes placed on said solid electrolyte so that an element current
4 flows in corresponding relation to a specific component concentration whenever a
5 voltage is applied to said sensor element, with the applied voltage being
6 controlled on the basis of an applied voltage characteristic defined in advance and
7 said specific component concentration in a gas to be detected being detected in a
8 wide range on the basis of an output of said element current,

9 the applied voltage is controlled in a region in which limiting current
10 regions overlap in a plurality of sensor output characteristics different in
11 temperature condition of the sensor element from each other.

1 48. The apparatus according to claim 47, wherein an output characteristic at a
2 minimum temperature in a temperature range actually attainable in a using
3 environment of said sensor element and an output characteristic at a maximum
4 temperature therein are employed so that the applied voltage is controlled in a
5 region in which limiting currents of said output characteristics overlap.

1 49. A gas concentration detecting apparatus for use in a limit-current type gas
2 concentration sensor comprising a sensor element including a solid electrolyte and
3 a pair of electrodes placed on said solid electrolyte so that an element current
4 flows in corresponding relation to a specific component concentration whenever a
5 voltage is applied to said sensor element, with the applied voltage being
6 controlled on the basis of an applied voltage characteristic defined in advance and
7 said specific component concentration in a gas to be detected being detected in a
8 wide range on the basis of an output of said element current,
9 an initial output characteristic of said sensor element and an estimated
10 output characteristic thereof after variation with time are used so that the applied
11 voltage is controlled in a region in which limiting current regions of said output
12 characteristics overlap.

1 50. The apparatus according to claim 49, wherein
2 said estimated output characteristic after the variation with time is an estimated
3 output characteristic at a deterioration tolerance limit permitting the use of an
4 output of said element current.

1 51. The apparatus according to claim 1, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a lean side limit of an air-fuel ratio
4 detection range is set at A/F20 or more.

1 52. The apparatus according to claim 2, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a lean side limit of an air-fuel ratio
4 detection range is set at A/F20 or more.

1 53. The apparatus according to claim 39, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a lean side limit of an air-fuel ratio
4 detection range is set at A/F20 or more.

1 54. The apparatus according to claim 40, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a lean side limit of an air-fuel ratio
4 detection range is set at A/F20 or more.

1 55. The apparatus according to claim 45, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a lean side limit of an air-fuel ratio
4 detection range is set at A/F20 or more.

1 56. The apparatus according to claim 46, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a lean side limit of an air-fuel ratio
4 detection range is set at A/F20 or more.

1 57. The apparatus according to claim 47, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a lean side limit of an air-fuel ratio
4 detection range is set at A/F20 or more.

1 58. The apparatus according to claim 49, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a lean side limit of an air-fuel ratio
4 detection range is set at A/F20 or more.

1 59. The apparatus according to claim 1, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a lean side limit of an air-fuel ratio
4 detection range is set at the atmosphere.

1 60. The apparatus according to claim 2, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a lean side limit of an air-fuel ratio
4 detection range is set at the atmosphere.

1 61. The apparatus according to claim 39, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a lean side limit of an air-fuel ratio
4 detection range is set at the atmosphere.

1 62. The apparatus according to claim 40, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas

3 emitted from a combustion engine, and a lean side limit of an air-fuel ratio
4 detection range is set at the atmosphere.

1 63. The apparatus according to claim 45, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a lean side limit of an air-fuel ratio
4 detection range is set at the atmosphere.

1 64. The apparatus according to claim 46, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a lean side limit of an air-fuel ratio
4 detection range is set at the atmosphere.

1 65. The apparatus according to claim 47, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a lean side limit of an air-fuel ratio
4 detection range is set at the atmosphere.

1 66. The apparatus according to claim 49, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a lean side limit of an air-fuel ratio
4 detection range is set at the atmosphere.

1 67. The apparatus according to claim 1, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a rich side limit of an air-fuel ratio
4 detection range is set at A/F11 or less.

1 68. The apparatus according to claim 2, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a rich side limit of an air-fuel ratio
4 detection range is set at A/F11 or less.

1 69. The apparatus according to claim 39, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a rich side limit of an air-fuel ratio
4 detection range is set at A/F11 or less.

1 70. The apparatus according to claim 40, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a rich side limit of an air-fuel ratio
4 detection range is set at A/F11 or less.

1 71. The apparatus according to claim 45, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a rich side limit of an air-fuel ratio
4 detection range is set at A/F11 or less.

1 72. The apparatus according to claim 46, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a rich side limit of an air-fuel ratio
4 detection range is set at A/F11 or less.

1 73. The apparatus according to claim 47, wherein said apparatus is made to
2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
3 emitted from a combustion engine, and a rich side limit of an air-fuel ratio
4 detection range is set at A/F11 or less.

- 1 74. The apparatus according to claim 49, wherein said apparatus is made to
- 2 detect an air-fuel ratio on the basis of an oxygen concentration in an exhaust gas
- 3 emitted from a combustion engine, and a rich side limit of an air-fuel ratio
- 4 detection range is set at A/F11 or less.